# PATENT SPECIFICATION

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## (54) PROCESS AND APPARATUS FOR THERMALLY CRACKING ORGANIC SOLID WASTE

(71) We, SANYO ELECTRIC COMPANY LIMITED, of 18 Keihanhondori 2-chome, Moriguchi, Japan, a Japanese Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention is concerned with a process and an apparatus for the thermal cracking of rubber-containing organic solid wastes, for example, tyres, rubber hose, golf balls and other rubber articles, with superheated steam so that the resulting water, carbon, oil and the like can be effectively utilised.

It is known to incinerate industrial wastes as one of the simplest methods of disposal but this method poses problems, such as air pollution and consumption of carbon, oil and like useful components as wastes. It is, therefore, desirable to provide a method of treating industrial wastes.

A process has already been proposed in which plastics present in industrial wastes are cracked by heating to 400 to 500°C. in steam in the absence of air (see published Japanese Patent Application No. 42603/1972).

It is also proposed to treat wastes of rubber-containing articles with a hot gas, such as an inert gas, at a temperature of 500 to 600°C. (see published Japanese Patent Application No. 76966/1974). Although the proposal discloses the use of nitrogen gas as a specific example of the hot gas a passing reference is made to the use of superheated steam. This publication further indicates that wastes of rubber-containing articles must be broken up to a predetermined size, usually in the range of 5 to 50 mm., before being subjected to thermal cracking. Thus, wastes of rubber articles, such as tyres, are not applicable to thermal cracking unless they have been crushed, which requires additional apparatus. This publication also discloses that the gas produced by the cracking is recovered as a fuel and the resulting oil and carbon products can be reused, whereas nothing whatever is mentioned about the water recovered. As far as we are aware, the recovered water contains oil and other pollutants because of the difficulty involved in complete separation and must be treated by a large-scale apparatus before being discarded into a river or the like.

One of the objects of the present invention is to provide a process and an apparatus by means of which rubber-containing organic solid wastes, such as tyres, industrial rubber hose, golf balls and the like, can be subjected to thermal cracking treatment without being broken up prior to treatment so that the wastes can be treated economically at a lower apparatus cost than in the previously known processes in which breaking up means are essential, without requiring large-scale apparatus.

Another object of the present invention is to carry out the termal cracking of rubber-containing organic solid wastes with superheated steam, with recycling of the resulting water, the necessity of treating effluent water thereby being substantially eliminated.

Another object of the present invention is to recover carbon of good quality, i.e. with a greatly reduced volatile content, which can, therefore, be used again for the production of tyres, rubber hose, golf balls and the like.

Still another object of the present invention is to provide a thermal cracking treatment which can be carried out within a short period of time.

Thus, according to the present invention, there is provided a process for thermally cracking an organic solid waste, comprising thermally cracking a rubber-containing organic solid waste with superheated steam obtained from a superheated steam generator of the internal heating type and recycling the water recovered by condensing the resulting cracked product and steam for use as a source of water for the steam generator.

By the term "rubber-containing organic solid wastes" used herein is meant to be

understood tyres, rubber hose for industrial use, golf balls and like wastes, which may also contain plastics in addition the rubber contained therein. The process of the present invention is particularly well-suited for the thermal cracking of large-sized waste articles, such as waste tyres.

The term "superheated steam generator of the internal heating type" used herein refers to a container in which sprayed water or water vapour or steam is heated by being brought into direct contact with a flame and is thereby converted into superheated steam. More specifically, the generator can comprise, for example, a combustion chamber having a combustion nozzle in its interior and provided with a water spray nozzle or steam inlet. Preferably, the superheated steam produced in the generator has a temperature of 500 to 900°C. during thermal cracking reaction. The superheated steam preferably has a pressure of 0.3 to 1.5 kg/cm$^2$ (gauge) during the thermal cracking reaction. Thus, according to the present invention, the thermal cracking of rubber-containing articles with superheated steam can be carried out at a low pressure. Therefore, the apparatus used need not have a pressure-resistant construction, which is advantageous from the point of view of safety and also means that the apparatus is inexpensive to make.

The present invention also provides an apparatus for thermally cracking a rubber-containing organic solid waste, comprising a superheated steam generator of the internal heating type, a thermal cracking reactor for thermally cracking rubber-containing organic solid waste with superheated steam from the generator, a condenser for condensing the cracked product and steam drawn off from the reactor and a receiver for the resulting condensate, the aforesaid components of the apparatus being arranged in the given order, and a pipe extending from the receiver to the generator for returning the recovered water.

For a better understanding of the present invention, reference will now be made to the accompanying drawings, in which:

Fig. 1 is a diagram showing one embodiment of the apparatus of the present invention for thermally cracking rubber-containing organic solid wastes;

Fig. 2 is a partial view in vertical section, showing a thermal cracking reactor; and

Fig. 3 is a cross-sectional view taken along the line A—A in Fig. 2.

Referring now to Fig. 1, an apparatus 1 for thermally cracking the waste comprises a superheated steam generator 2 of the internal heating type, a reactor 3 for thermally cracking the waste with superheated steam from the generator, a condenser 4 for condensing steam and cracked product drawn off from the reactor and a receiver 5 for the condensates, these means being arranged in the given order. A return line 6 for the water recovered and drawn off from the receiver 5 extends from the receiver 5 to the superheated steam generator 2.

The superheated steam generator 2 of the internal heating type, which produces superheated steam with a temperature of about 500 to about 900°C. at a pressure of about 0.3 to about 1.5 kg./cm$^2$ (gauge), comprises a combustion chamber 7, a water spray nozzle 8 mounted in the inner wall of the chamber and a combustion nozzle 9 within the chamber 7. The water return line 6 connected to the water spray nozzle 8 is provided with a water supply line 10, which serves to replenish the generator with water when the recovered water is insufficient. The combustion nozzle 9 is provided with a fuel supply line 12 and an air supply line 13. The line 12 has a fuel tank 14 containing a fuel, such as kerosene, and a flow meter 19, while the line 13 has a blower 21 and a flow meter 24 and is further provided with an air release line 25 for regulating the pressure of the combustion air. The combustion chamber 7 is provided on its inner wall with a recovered gas injecting nozzle 27. A feed line 28 extends from the generator 2 to the thermal cracking reactor 3 for feeding superheated steam to the reactor 3. A line 29 can be provided for controlling the internal pressure of the combustion chamber 7. The feed line 28 preferably has the shortest possible length in order to reduce the loss of heat from the superheated steam. It is preferable to omit the line 29.

Referring now to Figs. 2 and 3, the reactor 3 comprises a vertical cylindrical main body 32 and a residue container 33 positioned below the main body with an openable closure means 34 interposed therebetween. The cylindrical main body 32 has an inside diameter such that unbroken whole tyres T or the like can be stacked therein and comprises an outer cylinder 36 having a surrounding heat insulator 35, a lid 41 (see Fig. 1) for closing the top opening for introducing tyres T or the like, an annular retainer 43 at the bottom opening for supporting tyres T or the like in a horizontal position and an inner cylinder 39 extending downwardly from the approximate middle of the height of the outer cylinder 36 to form a superheated steam passage 37 between the outer cylinder 36 and the inner cylinder 39. The inner cylinder 39 is provided with a large number of small apertures 38, 38′, 38″, . . . for uniformly injecting superheated steam towards the vertical axis from the entire periphery of the cylinder. The superheated steam is introduced from the feed line 28 into the steam passage 37 through an inlet 42.

The residue container 33 has a door 45 on the lower side thereof and can accommodate a trolley 46 which can be withdrawn through

the door opening. The container 33 has a top opening provided with a support 50 opposed to the annular retainer 43. The retainer 43 and the support 50 each has an opening with an internal diameter such that bead wires 44 can fall therethrough. A rod 47 for engaging the bead wires 44 has an upper end positioned at the centre of the opening of the support 50 and a lower end pivotably supported by the outer wall of the container 33. A hook 49 engageable at the lower end of the rod 47 retains it in position.

The openable closure 34 is slidably interposed between the retainer 43 and the support 50 and is held closed during the thermal cracking of tyres T or the like to seal off the interior of the main body 32. The closure is equipped with hydraulic means 51.

Thus, tyres T or the like placed in the reactor 3 can be subjected to a uniform spray of superheated steam injected through the small apertures 38, 38′, 38″″, . . . . in the inner cylinder 39 and are thermally cracked within a short period of time. The gas produced flows upwardly, while the residue falls upon the underlying closure 34. When the closure 34 is opened after completion of the thermal cracking, the bead wires 44 in the residue are caught on the engaging rod 47 and the residue (i.e. carbon having a low content of volatiles) runs off into the trolley 46 and is withdrawn through the side opening after the door 45 has been opened. When the rod 47 is released from the hook 49, the bead wires 44 are placed into the trolley 46 and can, therefore, be similarly removed. Through an outlet 53, the gas produced flows into the condenser 4 by way of a dust collector 54 which is provided with a line 55 for discarding the dust collected.

Referring again to Fig. 1, the receiver 5 comprises a first receiver 57 and a second receiver 59 in communication with the receiver 57 and positioned below the bottom thereof. The first receiver 57 has a recovered gas return line 60 extending from an upper portion of the receiver 57 to the gas injecting nozzle 27. The return line 60 has a tank 61 containing a wash liquor (e.g. water or aqueous sodium hydroxide solution) for removing toxic gases, such as hydrogen sulphide, and a recovered gas tank 62. 68 indicates a line for releasing excess gas. The second receiver 59 is equipped with a condensed (recovered) water tank 72 and a recovered oil tank 73. The water tank 72 is connected to the water spray nozzle 8 by the water return line 6 provided with a pump 74. The oil tank 73 is connected to the fuel supply line 12 between a valve 16 and the flowmeter 19 by an oil return line 78 having a pump 76. 67 and 79 are liquid level indicators; 11, 16, 20, 22, 26, 56, 58, 63, 69, 70, 71, 75 and 77 are manual or electromagnetic valves; and 23, 31, 52, 64, 65 and 66 are pressure gauges.

With use of the apparatus 1 of the foregoing construction, tyres or the like are thermally cracked with superheated steam by the following process.

First, the lid 41 of the reactor 3 is opened and tyres or the like in their unbroken original shape are placed into the reactor 3 and stacked within the vertical cylindrical main body 32. The combustion nozzle 9 of the superheated steam generator 2 is fired. After steady operation has been established, recovered water is injected from the water return line 6 through the spray nozzle 8 into the combustion chamber 7. (If the amount of the water is insufficient, the chamber is appropriately replenished with water through the water supply line 10). The injected water is rapidly heated, forming superheated steam with a temperature of about 500 to about 900°C. and a pressure of about 0.3 to about 1.5 kg./cm² (gauge). By way of the feed line 28, the inlet 42 of the reactor 3 and the steam passage 37, the superheated steam is uniformly forced against the tyres T through the small apertures 38, 38′, 38″, . . . . provided in the inner cylinder 39. Consequently, the tyres T undergo a thermal cracking reaction with the aid of the superheated steam and are rapidly cracked into gas and residue. The cracked product is condensed in the condenser 4 and then separated into gas and liquid in the first receiver 57. The resulting gas portion may be recycled to the steam generator 2 *via* the return line 60. The liquid portion is left to stand in the second receiver 59 and thereby separates into oil and water. The oil portion is passed through the oil return line 78, while the water portion is passed through the water return line 6 and reused in the steam generator 2. Thus, the recovered water is recycled through the apparatus 1 for reuse, without any possibility of causing pollution which would result if the water is run off from the apparatus. The residue, when separated from bead wires 44, consists predominantly of carbon black having a low content of volatiles. The residue can be readily reused as a material for making rubber products.

The following Examples are given for the purpose of illustrating the present invention:—

Example 1.

Several kinds of waste standard tyres from ordinary motor vehicles were used. Four or five tyres of each kind were treated by the foregoing process with the use of the apparatus described above. For the initiation of the operation, about 20 litres of tap water were supplied to the apparatus. The required amount of water was subsequently provided by recycling the recovered water. The results obtained are given in the following Table I:

TABLE I

| Specimen | Weight of tyres treated (kg.) | Material balance % | | | | Cracking conditions | |
|---|---|---|---|---|---|---|---|
| | | Oil | Carbon | Bead Wire | Gas | Temp. (°C.) | Time (hr.) |
| $S_1$ | 29.5 | 49.5 | 33.9 | 4.1 | 12.5 | 530* | 5 |
| $S_2$ | 32.0 | 54.7 | 31.7 | 4.1 | 9.5 | 720 | 2 |
| $S_3$ | 30.4 | 55.9 | 33.6 | — | 10.5 | 760 | 2.2 |
| $S_4$ | 29.5 | 54.3 | 33.0 | 3.4 | 9.3 | 700 | 2 |

* Additionally heated by electric heater.

The proportion of the steam in the gas produced in the combustion chamber 7 for the treatment of Specimen $S_2$ and the properties of the carbon recovered therefrom are as follows:

Composition of the steam:

| | mol % |
|---|---|
| $CO_2$ | 2.14 |
| $H_2O$ | 84.65 |
| $N_2$ | 12.90 |
| $O_2$ | 0.31 |

Properties of the carbon recovered:

| | |
|---|---|
| Reduction due to heating | 0.9% |
| Volatiles * | 2.2% |
| Ash | 10.1% |
| Amount of iodine adsorbed | 104 mg/g. |
| Amount of dibutyl phthalate adsorbed | 100 ml/100 g. |
| pH | 9.6 |

* The carbon recovered by a conventional apparatus contains about 4.8 to about 8.6% of volatiles (see "Rubber Age", February, 1976).

The thermal cracking apparatus used had the following specifications:

Superheated steam generator 2:

| | |
|---|---|
| Rated capacity | 60,000 kcal/hr. |
| Fuel | kerosene |
| Turndown ratio | 1/5 |

Thermal cracking reactor 3:

| | |
|---|---|
| Inside diameter of vertical cylindrical main body | 800 mm. |
| Height of the main body | 3,000 mm. |

Example 2.

Wastes of special rubber products were treated in the same manner as in Example 1, the results obtained being given in the following Table II:—

TABLE II

| Specimen | Weight of material treated (kg.) | Material balance (%) | | | | Cracking conditions | |
|---|---|---|---|---|---|---|---|
| | | Oil | Carbon | Bead wire | Gas | Temp. (°C.) | Time (hr.) |
| Carbon-containing rubber* + types + polyethylene + waste oil | 30.2 | 54.0 | 30.8 | 3.6 | 11.6 | 700 | 2 |
| Golf balls | 25.0 | 55.2 | 31.6 | — | 13.2 | 730 | 2 |
| Tyre filler | 30.0 | 49.0 | 2.3 | — | 48.6 | 730 | 2 |
| Carbon-containing rubber* | 31.1 | 41.8 | 31.5 | 4.2 | 22.5 | 770 | 2.5 |

* Waste from tyre manufacturing process.

WHAT WE CLAIM IS:—

1. A process for thermally cracking an organic solid waste, comprising thermally cracking a rubber-containing organic solid waste with superheated steam obtained from a superheated steam generator of the internal heating type and recycling the water recovered by condensing the resulting cracked product and steam for use as a source of water for the steam generator.

2. A process according to claim 1, wherein the superheated steam used has a temperature of 500 to 900°C.

3. A process according to claim 1 or 2, wherein the superheated steam used has a pressure of 0.3 to 1.5 kg/cm$^2$ (gauge).

4. A process according to any of the preceding claims, wherein the rubber-containing organic solid waste is thermally cracked without being broken up.

5. A process according to claim 1 for thermally cracking organic solid waste, substantially as hereinbefore described and exemplified and with reference to the accompanying drawings.

6. An apparatus for thermally cracking a rubber-containing organic solid waste, comprising a superheated steam generator of the internal heating type, a thermal cracking reactor for thermally cracking rubber-containing organic solid waste with superheated steam from the generator, a condenser for condensing the cracked product and steam drawn off from the reactor and a receiver for the resulting condensate, the aforesaid components of the apparatus being arranged in the given order, and a pipe extending from the receiver to the generator for returning the recovered water.

7. An apparatus according to claim 6, wherein the thermal cracking reactor is provided at its lower end with means for withdrawing the carbon resulting from thermal cracking.

8. An apparatus according to claim 6 for thermally cracking rubber-containing organic solid waste, substantially as hereinbefore described and with reference to the accompanying drawings.

9. Carbon substantially free of volatiles, whenever produced by the process according to any of claims 1 to 5.

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1507138 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

**Sheet 1**

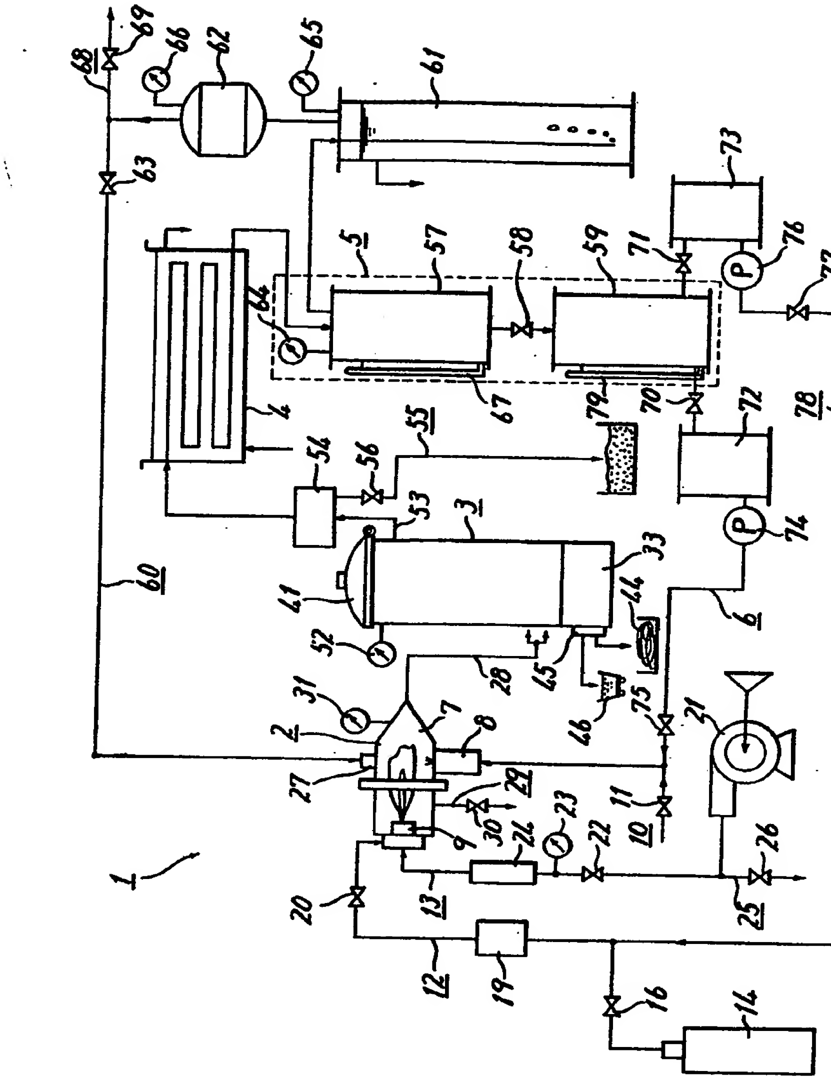

FIG. 1

1507138 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

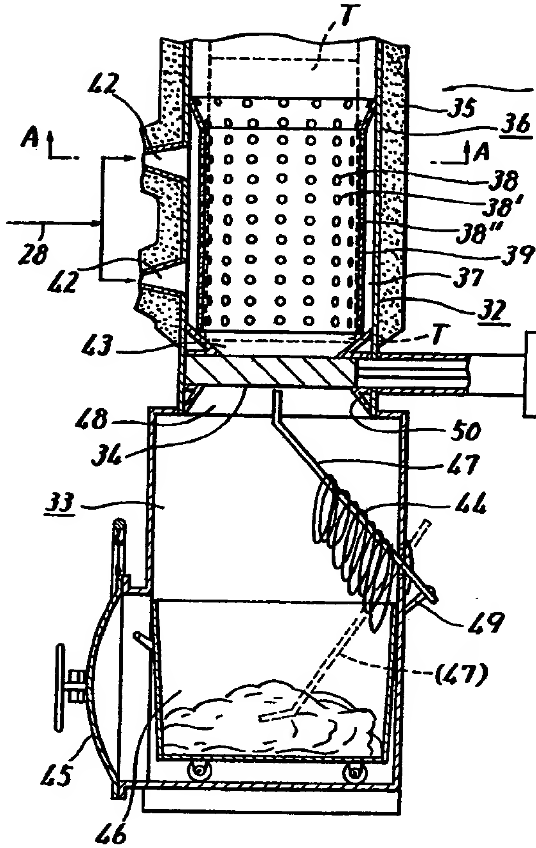


FIG. 2

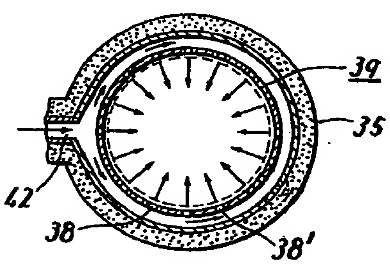


FIG. 3